

1

MEMBRANE BASED FUEL DEOXYGENATOR

TECHNICAL FIELD

This invention relates to the removal of oxygen from fuels and more particularly, to the removal of dissolved oxygen from liquid hydrocarbon fuels.

BACKGROUND ART

Because of its relative abundance in the air of the atmosphere, relatively large quantities of oxygen, as well as nitrogen and other gases, readily dissolve into various liquid media. The presence of dissolved oxygen, in particular, in some liquids, such as hydrocarbon fuels, may be objectionable because it supports oxidation reactions that yield undesirable by-products.

For instance, jet fuel in aircraft may be used as a coolant for various systems in the aircraft. When air-saturated fuel is heated to temperatures above about 250° F. –300° F., the dissolved oxygen reacts to form free radical species (coke precursors) which initiate and propagate other autoxidation reactions leading to the formation of objectionable deposits, called “coke” or “coking”. This relationship is illustrated in FIG. 1 for jet fuel, where it is seen that as temperature increases beyond about 150° C. (300° F.), the process of autoxidation consumes oxygen and forms carbonaceous deposits. The temperature at which autoxidation begins differs for different fuels. These autoxidation reactions may also occur in jet fuel as it is heated immediately prior to injection for combustion, such that deposits may occur in the injectors. In any event, the formation of such deposits impairs the normal functioning of a fuel delivery system, either with respect to an intended heat exchange function or the efficient injection of fuel.

Still further, such autoxidation reactions may create objectionable deposits by oxygen-laden hydrocarbon fuels when used in other energy conversion devices and systems, as for instance fuel cells.

Referring to FIG. 2, the above mentioned reaction path is dominant at temperatures up to about 700° F., but becomes unimportant when the concentration of dissolved oxygen is reduced from its saturated value (about 70 ppm) to very low levels (5 ppm or less). Indeed, reduction of the dissolved oxygen to levels less than 20 ppm and particularly less than 10 ppm, yield dramatic reductions in the formation of deposits by autoxidation reactions. Since pyrolysis occurs at higher temperatures than autoxidation, reducing the oxygen concentration allows the fuel to be heated to a higher temperature before thermal decomposition occurs.

Previous methods of reducing the oxygen content of fuels are discussed in a report, dated Oct. 1988, by S. Darrah entitled “Jet Fuel Deoxygenation” under Air Force Contract F33615-84-C-2412. These methods included the use of chemical getters (reducing agents), molecular sieve adsorbents, and nitrogen sparging. The report discussed each in some detail, and expressed a preference for nitrogen sparging for large quantities of fuel. However, each of these methods has proven impractical at least for aircraft applications because they are costly, heavy and bulky, and/or may even be dangerous. Chemical getters involve the use of active metals, which pose containment and disposal issues. Molecular sieves do not pose reactivity limitations, but present issues of volume and weight, particularly in aircraft. Nitrogen sparging may be unfeasible because of the volume of nitrogen required during a mission.

What is needed is a method and/or means for deoxygenating hydrocarbon fuel in a cost effective, size efficient,

2

weight efficient, and/or safe manner. The fuel deoxygenation technique should be capable of on-line operation, i.e., continuous use at flow rates which are consistent with the rate of fuel use in the intended energy conversion device, such as an aircraft jet engine or the like. Moreover, the deoxygenation technique should be capable of removing oxygen to a level at least below that at which significant coking would otherwise occur. As used herein, “significant coking” is the minimum amount of coking which, if it occurred in the interval between normal intended maintenance events for such portions of the fuel system, would be viewed as objectionable. Such coking occurs most readily in the portions of the fuel system having high temperatures and/or constricted flow paths.

DISCLOSURE OF INVENTION

The present invention relates to the deoxygenation of liquid fuel in the fuel system of an energy conversion device. More particularly, the present invention relates to a method and to a deoxygenator apparatus for removing dissolved oxygen from the liquid fuel in a cost effective, weight efficient and/or safe manner.

According to the present invention, there is provided a fuel deoxygenator having a membrane filter disposed in a liquid fuel system. The membrane filter is of such material, and is positioned, structured, and operated for liquid fuel to flow into contact with a fuel-side surface of the filter such that oxygen is removed from the fuel to a level at least below that at which significant coking occurs. The membrane filter passes oxygen molecules and excludes the liquid fuel sufficiently to remove oxygen from the fuel to a level at least below 20 ppm, preferably below about 10 ppm at a liquid space velocity

$$\left(SV = \frac{\text{volume flowrate}}{\text{reactor volume}} = \frac{1}{\text{residence time}} \right)$$

of at least 100/hr., and more preferably, to a level of about 5 ppm.

The membrane filter may be a permeable membrane which operates by a solution-diffusion mechanism, such as silicone-rubber; a porous membrane that operates by allowing dissolved oxygen to diffuse through angstrom sized pores, such as a layer of zeolite particles; or, preferably, is from the family of polytetrafluoroethylene type compounds. The membrane filter may be disposed on the surface of a porous substrate for support.

The fuel system includes a deoxygenation chamber, with the membrane filter so structured and positioned therein as to provide a fuel region and a removed oxygen region on opposite sides of the filter. Means may be provided for regulating the partial pressures of oxygen across the membrane to regulate the driving force for moving oxygen through the membrane. In the interest of safety, any possible fuel leaks through the membrane filter are isolated from the environment by returning fuel and/or gases in the removed oxygen region to a fuel tank.

The foregoing features and advantages of the present invention will become more apparent in light of the following detailed description of exemplary embodiments thereof as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 graphically depicts the corresponding consumption of oxygen and formation of deposits as fuel temperature increases;